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LOGANEnergy Corp.

Keesler AFB PEM Demonstration Project
Final Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Keesler Air Force Base, MS Senior Officer's Quarters

August 30, 2006

Executive Summary

Under terms of its FY'03 DOD PEM Demonstration Contract with ERDC/CERL, LOGANEnergy will install and operate a Plug Power GenSys 5kW_e Combined Heat and Power fuel cell power plant at Keesler AFB. The unit was sited at the residence of Lt. Col. T. Yang, commander of the Civil Engineering Squadron. It was electrically configured to provide grid parallel/grid independent service to the Colonel's residence and also thermally integrated with a small Munters HVAC desiccant air unit to provide cool dry air to support the air conditioning system at the residence. It was anticipated that the project will add an additional \$483.35 in energy costs to the base during the period of performance.

Midway through the project, on August 29, 2005, Hurricane Katrina struck the Gulf Coast with devastating winds and major flooding. The eastern wall of the hurricane eye passed over Keesler causing significant damage to the base including the fuel cell project. In the aftermath, Keesler advised LOGAN that the project would have to come to a close. Since the base was closed to visitors for three months following the hurricane passage, LOGAN was unable to restore the site until mid December 2005.

The POC for this project was Lt Michael Fuller, whose phone number is 228.377.3801 and whose email address is michael.fuller@keesler.af.mil.

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Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

LOGANEnergy Corp. Small Scale PEM 2004 Demonstration at Keesler AFB, MS.

2.0 Name, Address and Related Company Information

LOGANEnergy Corporation

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BLDG 100- 175
Roswell, GA 30076
(770) 650- 6388

DUNS 01-562-6211
CAGE Code 09QC3
TIN 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 30 commercial and small-scale fuel cell projects totaling over 7 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 30 PAFC and PEM fuel cell projects at 21 locations in 12 states, and has agreements to install 22 new projects in the US and the UK over the next 18 months.

3.0 Production Capability of the Manufacturer

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P LP Gas unit, and the GenCore 5kW standby power system. The current facility has the capability of manufacturing 10,000 units annually. Plug will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Scott Wilshire is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1338, and his email address is scott_wilshire@plugpower.com.

4.0 Principal Investigator(s)

Name	Samuel Logan, Jr.	Keith Spitznagel
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5.0 Authorized Negotiator(s)

Name	Samuel Logan, Jr.	Keith Spitznagel
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6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022

Merck & Company
Ms. Stephanie Chapman
Merck & Company
Bldg 53 Northside
Linden Ave. Gate
Linden, NJ 07036
(732) 594-1686

Contract: Four-year PC25 PM Services Maintenance Agreement.

In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Patuxant River, MD. .

Plug Power
Mr. Vinny Cassala
968 Albany Shaker Rd.
Latham, NY 12110
(518) 782-7700 ex 1228

LOGAN performed the start-up of both units after Southern Maryland Electric Cooperative completed most of the installation work and continues to provide service and maintenance during the period of performance.

- c) Contract: A Partners LLC Commercial Fuel Cell Project Design, Installation and 5-year service and maintenance agreement.

Contract # A Partners LLC, 12/31/01

Mr. Ron Allison
A Partner LLC
1171 Fulton Mall
Fresno, CA 93721
(559) 233-3262

On April 20, 2004 LOGAN completed the installation of a 600kWe PC25C CHP fuel cell installation in Fresno, CA.

7.0 Host Facility Information



Keesler Air Force Base, in Biloxi, Mississippi, is located approximately 83 miles east of New Orleans, Louisiana, and approximately 65 miles west of Mobile, Alabama.

Keesler is part of Air Education and Training Command, and its primary mission since 1941 has been training. The emphasis is on high-technology training

in a number of fields, primarily in the electronics specialties. Avionics maintenance, radio and radar systems maintenance, communications-electronics, computer systems programming and maintenance, air traffic control, and weather training are but a few of the main specialties taught at Keesler.

Keesler AFB is home to the 81st Training Wing, one of Air Education and Training Command's largest technical training wings.

Keesler opened in 1941, when the city of Biloxi deeded 1,563 acres of land to the government for an Army Air Corps technical training base for airplane and engine mechanics.

The base was named in honor of 2nd Lt. Samuel Reeves Keesler Jr., an Aerial observer from Greenwood, MS, who was killed in action in France during World War I. During World War II, 142,000 aviation mechanics and 336,000 new recruits were trained at

Keesler. The majority of the B-24 "Liberator" bomber mechanics were Keesler trainees. Many other schools operated at Keesler during the war, including the B-24 copilot and emergency rescue schools.

During the 1970s, Keesler remained the largest training center in the Air Force and became the nation's main supplier of electronics technicians. Two additional areas of training received special attention in the 1980s-- airborne warning and control systems and ground launched cruise missile. The air traffic control program also received its share of attention, especially during the 1981 professional air traffic controllers' strike. By presidential order, military controllers, trained at Keesler, stepped in and kept the nation's airways flowing.

In 1992, Keesler began training all of the DOD's weather forecasters and observers when it gained courses from the closing of Chanute AFB, IL. Flying training returned once again in 1994 with the instruction of pilots in the C-12 and C21 aircraft.

Mississippi Power is the electric service provider and Center Point is the natural gas provider to Keesler AFB.

8.0 Fuel Cell Installation

After LOGAN conducted a preliminary site visit on August 25, 2004 with Lt Mike Fuller, Keesler POC, and following consultations with Lt. Col. T. Yang CE Squadron Commander, it was determined that Lt. Col. Yang's residence would be the first choice for the demonstration site. The photos of the colonel's residence, Figures 1 and 2, were taken during the visit.

The unit operates normally in a grid parallel configuration at a set point of 2.5kW. At this power dispatch rate the Gensys5C unit consumes 3345 scf with a nominal LHV of 945 btu/scf of natural gas.



Figure 1- Residential Site



Figure 2- Fuel Cell Site

Electric utility connections are located on the garage exterior wall behind the fuel cell pad site location as viewed in Figure 3, below. Natural gas service for the fuel cell is located

about 120 feet from the proposed pad site, but the routing did not impose any significant installation problems.

Installation was completed, as viewed below in [Figure 4](#), at this site on March 4, 2005, and required 86.25 man-hours. The fuel cell passed the acceptance test and was commissioned on March 7, 2005. See [Appendix 2](#) for the checklist.



Figure 3- Electric Utility Connection



Figure 4- Completed Installation

Keesler AFB PEM Fuel Cell Installation One-Line Diagram

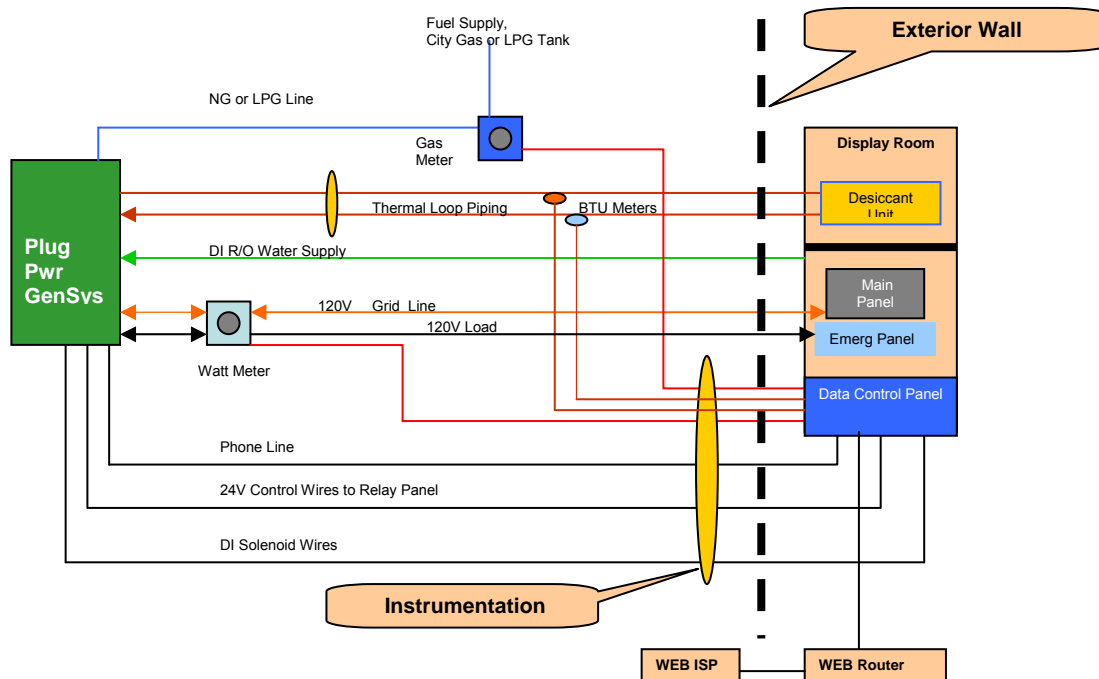


Figure 5

Diagram of electrical, mechanical, thermal, and communications interfaces between the fuel cell and the host facility.

9.0 Electrical System

The Plug Power GenSys 5C PEM fuel cell power plant provides both grid parallel and grid independent operating configurations for site power management. This capability is an important milestone in the development of the GenSys5 product and for the PEM Program itself, as it is a significant developmental step on the pathway to product commercialization. The unit has a power output of 110/120 VAC at 60 Hz, and when necessary the voltage can be adjusted to 208vac or 220vac depending upon actual site conditions. Figure 3, above, shows the electrical service panel on the rear wall of Col Yang's garage where the fuel cell was electrically coupled to the base utility grid. A new fuel cell emergency panel was installed adjacent to the existing panel and has several non-critical circuits totaling 35 amps attached to simulate the fuel cell's stand-by power application.

10.0 Thermal Recovery System

While operating at a set point of 2.5 kW, the GenSys5C has a heat rate 35,200Btu/H and offloads approximately 7,800Btu/H to the internally mounted customer heat exchanger. In an ongoing attempt to develop a total fuel cell energy solution that optimizes this waste heat opportunity, LOGAN installed a Munters Corp. H300 Cargocaire desiccant dehumidifier at this site. As Keesler AFB is located in the southern US where high humidity increases air-conditioning loads, adds to utility costs, and raises other indoor environmental concerns, LOGAN believes desiccant air-conditioning may be the best use of low quality waste heat from the fuel cell to combat these issues. The residence of Lt. Col T. Yang currently has an active air conditioning system, however by supplementing the air conditioning system with desiccant air-conditioning the humidity levels will be reduced as well as the workload of the current air conditioning system. After reviewing the products offered by several manufacturers, LOGAN selected the Munters H300, which has a long operating life for humidity control at virtually any temperature with the following additional advantages:

- Efficient humidity control for applications including product drying, mold and mildew control, corrosion protection, storage and condensation control.
- Durable unitized body with welded aluminum construction.
- Easy access panel for inspection and maintenance. Simple ductwork connections.
- Compact, low profile design.
- Flow rates of 150-300 scfm
- Nominal moisture removal; 9.1 lbs/hr at 75F, 50% RH at 300 scfm. Capable of processing saturated, conditioned or outside air.

Figure 6, below, is a close up of the Munters H300 unit installed at the residence of Lt. Col. T. Yang PEM demonstration site in Biloxi, MI.



Figure 6

11.0 Data Acquisition System

LOGAN has installed a Connected Energy Corporation web based SCADA system that provides real time monitoring of the power plant. The schematic drawing seen in [Figure 7](#) describes the architecture of the CEC hardware that supports the project. The system provides a comprehensive data acquisition solution and also incorporates remote control, alarming, notification, and reporting functions. The system picks up and displays a number of fuel cell operating parameters on functional display screens including kWh, cell stack voltage, and water management, as well as external instrumentation inputs including Btu, fuel flow, and thermal loop temperatures. LOGAN's Operations Control Center in Rochester, New York, collects, stores, displays, alarms, archives site data, and maintains connectivity by means of a Virtual Private Network that links the fuel cell to the control center.

CEC WEB enabled SCADA terminal hardware.

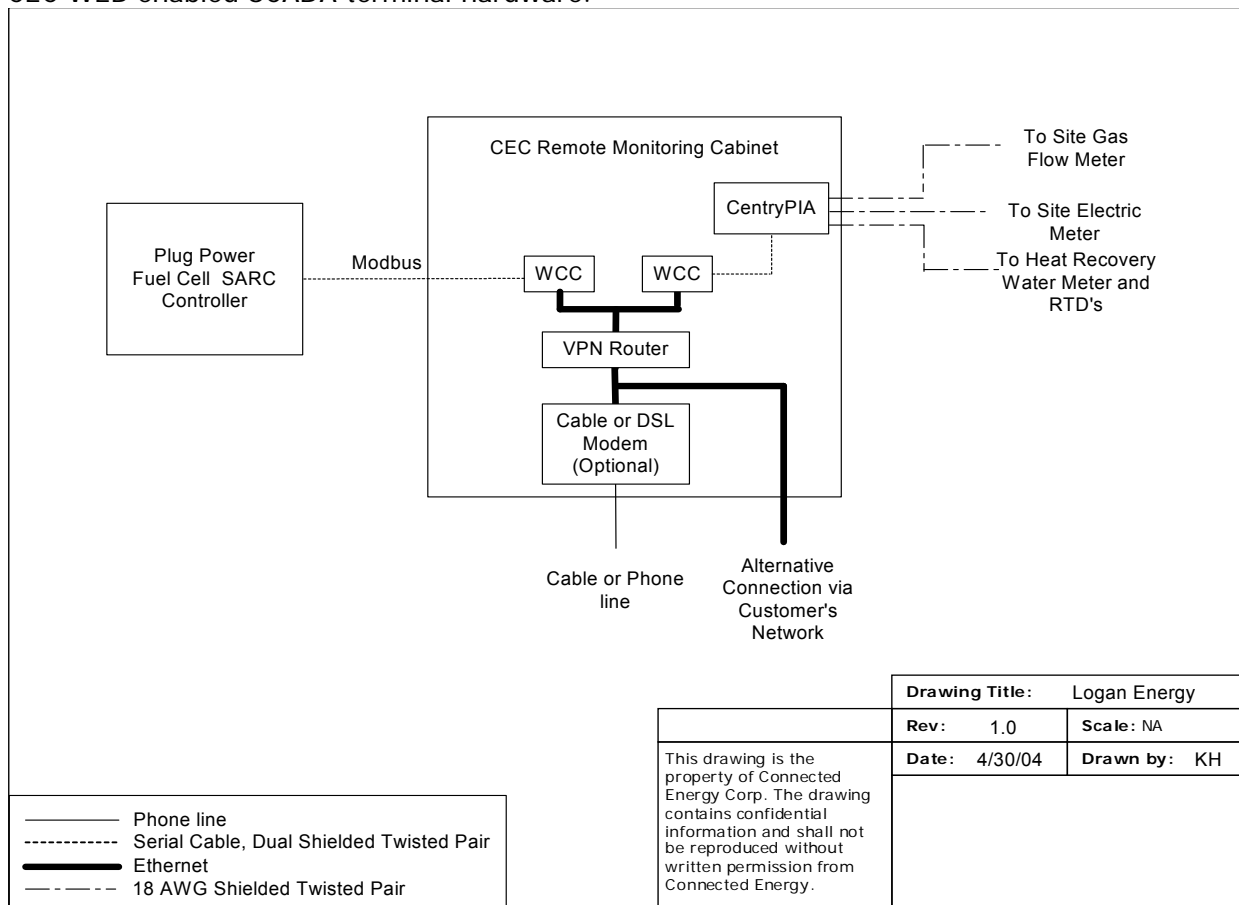


Figure 7

12.0 Fuel Supply System

LOGAN connected the fuel cell gas piping into the existing natural gas service line adjacent to the fuel cell pad, and installed a flow meter to calculate fuel cell usage as detailed in Paragraph 8.0. A regulator at the fuel cell gas inlet maintains the correct fuel cell operating pressure at 14 inches water column. The local natural gas provider is Center Point.

13.0 Program Costs

Keesler AFB, MS				
Project Utility Rates			Providers	
1) Water (per 1,000 gallons)	\$	0.85	City of Biloxi	
2) Utility (per KWH)	\$	0.045	Mississippi Power	
3) Natural Gas (per MCF)	\$	6.00	Center Point	
First Cost		Estimated	Actual	Variance
Plug Power 5 kW SU-1		\$ 65,000.00	\$ 65,000.00	\$ -
Shipping		\$ 2,400.00	\$ 2,482.00	\$ (82.00)
Installation electrical		\$ 2,800.00	\$ 3,928.00	\$ (1,128.00)
Installation mechanical & thermal		\$ 6,300.00	\$ 10,234.00	\$ (3,934.00)
Watt Meter, Instrumentation, Web Package		\$ 1,285.00	\$ 2,000.00	\$ (715.00)
Site Prep, labor materials		\$ 825.00	\$ 1,220.00	\$ (395.00)
Technical Supervision/Start-up		\$ 4,500.00	\$ 4,500.00	\$ -
Total		\$ 83,110.00	\$ 89,364.00	\$ (6,254.00)
Assume Five Year Simple Payback		\$ 16,622.00	\$ 17,872.80	
Forecast Operating Expenses		Volume	\$/Hr	\$/ Yr
Natural Gas Mcf/ hr @ 2.5kW	0.0330	\$	0.20	\$ 1,561.03
Water Gallons per Year	14,016			\$ 11.91
Total Annual Operating Cost				\$ 1,572.95
Economic Summary				
Forecast Annual kWH		19710		
Annual Cost of Operating Power Plant		\$	0.080	kWH
Credit Annual Thermal Recovery Rate			(\$0.010)	kWH
Project Net Operating Cost		\$	0.070	kWH
Displaced Utility cost		\$	0.045	kWH
Energy Savings (Cost)		(\$0.025) kWH		
Annual Energy Savings (Cost)		(\$483.35)		

Explanation of Calculations:

Actual First Cost Total is a *sum* of all the listed first cost components.

Assumed Five Year Simple Payback is the Estimated First Cost Total *divided by* 5 years.

Forecast Operating Expenses:

Natural gas usage in a fuel cell system set at 2.5 kW will consume 0.033 MCF per hour. The cost per hour is 0.033 MCF per hour \times the cost of natural gas to the site per MCF at \$6.00. The cost per year at \$1561.03 is the cost per hour at \$0.20 \times 8760 hours per year \times 0.9. The 0.9 is for 90% availability.

Natural gas fuel cell systems set at 2.5 kW will consume 1.6 gallons of water per hour through the DI panel. The total volume of water consumed at 14,016 gallons per year is 1.6 gph \times 8760 hours per year. The cost per year at \$11.91 is 14,016 gpy \times cost of water to the site at \$0.85 per 1000 gallons.

The Total Annual Operating Cost, \$1572.95 is the *sum of* the cost per year for the natural gas and the cost per year for the water consumption.

Economic Summary:

The Forecast Annual kWh at 19,710 kWh is the product of the 2.5 kW set-point for the fuel cell system \times 8760 hours per year \times 0.9. The 0.9 is for 90% availability.

The Annual Cost of Operating the Power Plant at \$0.080 per kWh is the Total Annual Operating Cost at \$1572.95 *divided by* the forecast annual kWh at 19,710 kWh.

The Credit Annual Thermal Recovery at -\$0.010 is 7800 *divided by* 3414. This is then *multiplied by* 0.1 \times the cost of electricity at \$0.045 per kWh \times (-1). As a credit to the cost summary, the value is expressed as a negative number.

The Project Net Operating Cost is the *sum of* the Annual Cost of Operating the Power Plant *plus* the Credit Annual Thermal Recovery.

The Displaced Utility Cost is the cost of electricity to Stennis per kWh.

Energy Savings (cost) equals the Displaced Utility Cost *minus* the Project Net Operating Cost.

Annual Energy Savings (cost) equals the Energy Savings \times the Forecast Annual kWh.

14.0 **Milestones/Improvements**

This project fell short of the desired goals and achievements because of the destruction to the base and local region caused by Hurricane Katrina on 29 August 2006.

15.0 **Decommissioning/Removal/Site Restoration**

In late January 2006, Keesler allowed LOGAN entry to the base to decommission the fuel cell and restore the site. When the technician arrived he took a number of photos to document the damage to the base and to the fuel cell unit. The photos below provide ample evidence of the destruction caused by the hurricane and damage to the fuel cell unit itself. Following discussions with the POC, it was decided that the base would take possession of the ruined fuel cell and dispose of it along with the tons of damaged equipment and debris left in the wake of the hurricane. LOGAN removed the transformer

and Munters unit and turned possession of the remainder of the installation to the base, which shortly thereafter leveled Col Yang's residence as it was damaged beyond repair.



Figure 8 ...Typical property destruction at Keesler AFB following Hurricane Katrina.



Figure 9...Photo showing water level inside fuel cell arising from Gulf Coast storm surge.

16.0 Additional Research/Analysis

This project featured for the first time an attempt to install a fuel cell total energy package through integration with an HVAC appliance. To do this a Munter's H300 desiccant air condition unit was installed at the colonel's home to test the efficiency of using waste heat from the fuel cell to satisfy the thermal load required by the desiccant unit. The fuel cell's waste heat output was plumbed to a coil within the desiccant unit to transfer the heat to the incoming airflow through the coil. Outdoor humidity on the Mississippi Gulf Coast the region is typically above 85% in the summer months and averages above 70% in the winter months. The desired effect is to dry and filter the incoming air to 50% relative humidity to improve indoor air quality and reduce the air conditioning energy requirements to only that necessary to satisfy the sensible air conditioning load.

Unfortunately the hurricane interrupted the project and loss of data. However LOGAN has planned to install this system at another location in the near future to go forward with the investigation.

17.0 Conclusions/Summary

But for the Hurricane Katrina, the Keesler project was on an investigative path to reveal new information and a better understanding of how to integrate a 5kW residential fuel cell power plant with an HVAC appliance in the built environment. Fortunately the lessons learned in planning and developing such a project have not been lost and will be replicated at another location where the investigation can continue.

LOGAN believes that it is important to develop these methods and best practices so that when fuel cells achieve commercial status, the industry will understand cost effective installation techniques to achieve widespread market appeal within and without DOD.

Appendix

1) Monthly Performance Data

Keesler AFB, Biloxi, Mississippi	March, 2005	April, 2005	May, 2005	June, 2005	July, 2005	August, 2005	September, 2005	Total
Run Time (Hours)	660	720	744	612	720	478	—	3934
Time in Period (Hours)	744	720	744	720	744	747	—	4419
Availability (%)	89%	100%	100%	85%	97%	64%	—	89%
Energy Produced (kWe-hrs AC)	1840	1786	1855.8	1535.1	1070	1179	—	9265.9
Output Setting (kW)	2.5	2.5	2.5	2.5	2.5	2.5	—	2.5
Average Output (kW)	2.79	2.48	2.49	2.51	1.49	2.47	—	2.36
Capacity Factor (%)	55.76%	49.61%	49.89%	50.14%	29.72%	49.34%	—	47.10%
Fuel Usage, LHV (BTUs)	2.42E+07	2.32E+07	2.47E+07	2.05E+07	1.95E+07	2.39E+07	—	1.36E+08
Fuel Usage (SCF)	302	288	308	255	243	297	—	1693
Electrical Efficiency (%)	25.91%	26.33%	25.62%	25.58%	18.71%	16.86%	—	23.26%
Thermal Heat Recovery (BTUs)	0	0	0	0	0	0	—	0
Heat Recovery Rate (BTUs/hour)	0	0	0	0	0	0	—	0
Thermal Efficiency (%)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	—	0.00%
Overall Efficiency (%)	25.91%	26.33%	25.62%	25.58%	18.71%	16.86%	—	23.26%
Number of Scheduled Outages	0	0	0	0	0	0	—	0.00%
Scheduled Outage Hours	0	0	0	0	0	0	—	0.00%
Number of Unscheduled Outages	1	0	0	1	1	1	—	4
Unscheduled Outage Hours	84	0	0	36	24	266.14	—	410.14